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PENETRATING THE SECRETS OF LIFE

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[Following is the translation of an article entitled "Pronikaya v tayny zhizni" (English version above) by G. Frank in Nedelya (Sunday Supplement of Izvestiya), No 30, Moscow, 18-24 September 1960, page 9.]

Glancing at a page of Izvestiya devoted to the rapid progress of our science during the past quarter-centry, Academician A. N. Nesmeyanov pointed out the basic characteristics of this progress: the rise and rapid development of related scientific fields. He said that the "junction" of separate disciplines is infusing new life into each individual science. In this way new and previously unknown features of science originate; they in turn sometimes occasion further progress.

The great penetration of chemistry and, more recently, physics into biology has characterized biological science for the past quarter-century. Biochemistry has grown into an independent discipline with many branches, and the chemical investigation and analysis of biological phenomena is penetrating the various fields of modern biology. The penetration of physics into most branches of biology has created the new field of biophysics.

If we imagine contemporary experimental biologists as they were a quarter-century ago, we can graphically evaluate the progress made since then. This mental "time machine" enables us to see that, from the modern point of view, we were then empty-handed. The new experimental devices and ideas that have made possible the great scientific advances of the past quarter-century have spoiled us.

Really, can one imagine an experimental biologists today without an electronic microscope? Twenty-five years ago no one suspected that there would ever be an electronic microscope. To realize the full significance of the revolution this method has caused, we must recall something much discussed in our time. The advent of the ordinary, i.e., "light", microscope led to the development of new biological disciplines: cytology, histology, and microbiology. The microscope was put to practical use in biology, medicine, and agriculture. Though the potentialities of ordinary microscopy for a long time appeared practically exhausted, during the last twenty-five years electronic

optics overcame the seemingly insurmountable limit of the ordinary microscope's effective magnifications. Ordinary microscopes can magnify up to 2000 times; electronic microscopes can now magnify the structure of living objects up to two million times! The scientist can now discover directly the secrets of the molecular structure of biological objects. The ordinary microscope enables us to see, describe, and systematize structures invisible to the naked eye; electronic microscopy brings us closer to the understanding of the essence of molecular organization, for it builds a bridge connecting morphology (the science of structure) with physical and organic chemistry. The direct observation of a virus particle, inaccessible to the ordinary light microscope, would have been regarded as fantastic twenty-five years ago. Modern technology even makes it possibel to cut a virus into small slices so that the molecular "wrapping" in its various layers can be studies.

The penetration of physics into biology is not an isolated instance. The same can be said of the use of isotopes in biology. Various questions concerning metabolism, i.e., the complex combination of chemical processes lying at the base of life, are now being studied with the aid of isotope indicators. The electronic microscope has revealed previously invisible structures: isotope indicators have made visible the paths of movement and displacement of substances in the process of metabolism. The determination of the true speeds of many processes was the main accomplishment of isotope indicators, for this was impossible by ordinary chemical means. A quarter of a century ago biologists were relatively helpless in the study of metabolism, the most important basis of life.

Isotope indicators, arising out of the successes of atomic physics, are only one example of how physics goes hand in hand with chemistry in the understanding of the nature of life. The union of physics and chemistry in research on the basis of life is now taken for granted; the results of joint research have been most fruitful and have revealed new perspectives. Physics not only aids chemistry; in some ways, paradoxical as it may seem, it is beginning to surpass it in the discovery of the chemical bases of life.

Chemical methods of research know no competition in the study of chemical composition. They can best determine the distinctive character and specific activity of the innumerable chemical substances participating in living phenomena. But in the case of rapid chemical processes, which cannot be studied if the substance of the living tissue and cells under observation is destroyed, a special chemistry of living functioning tissue becomes necessary. Chemical changes in living functioning tissue must be registered without stopping the complex sequence of metabolism. This is the subject of modern physical biochemistry, in which the border between the physics and chemistry of life vanishes; the first steps are taken in studying chemical changes without interfering with these changes, without interruption of metabolism.

The isotope indicators mentioned above represented only the first stage in the development of this field. Numerous methods have revealed previously unsuspected phenomena: paramagnetic resonance, molecular spectroscopy, etc. Twenty-five years ago the very possibility of such profound investigation of chemical processes in living functioning tissue would have seemed unfounded fantasy.

Contemporary biology, therefore, develops concurrently with related fields. Chemistry and biology, physics and biology not only form a partnership; perhaps it would be better to speak of a "knot" of cooperation, of the simultaneous contact of biology with chemistry, physics, and, especially, technology. This is more than a fusion or a determination of the degree of division and interaction among the sciences; new technical means of experimentation have made possible a synthesis of complex approaches. Method and research techniques have never been so decisive as today.

Twenty-five years ago biology practically remained biology in its pure form. Contact with physics and technology was limited to the application of one or another apparatus or method. At the present time method is acquiring independent importance. The exceptional position of biology is not the sole cause of this. One can even say that nuclear physics used accelerators as a method of solving scientific problems. The development of accelerators has become an independent scientific task of major significance. The same is true of biology, where different kinds of technical methods and their application have become an important branch of biological science. These sciences require competence in the researcher far exceeding the bounds of purely biological concepts. Because of the complicated relationship among the various fields of knowledge, the intimate connection between radio-electronics and biology does not appear accidental.

We are concerned here not only with extremely complicated methodology and technology, but also with the profound organic connection between sciences, especially in the development of theories about the regulation and "automatics" of life. Modern technology has still not fathomed the complexity and perfection of the regulating mechanisms that govern the several "levels" of life from cell to complete organism. Modern technology is still working on the solution of the problems of self-regulation and self-adjustment to the best working regimen that nature solved millions of years ago for each cell. In this way previously unsuspected phenomena have come to light and have been investigated: the remarkable mechanisms that automatically control life processes; reactions to various stimuli that are directed toward the preservation of the whole; even the self-regulation of organic growth that forms the basis of heredity. A quarter-century ago the regularity of heredity was observed from a purely external and formal point of view; since then new perspectives have been revealed, e. g., the connection between the "regulation" of growth and the transfer of corresponding hereditary marks by certain catalysts -- the ferments or chemical carriers of properties which seem to "program" biological processes.

The interrelation of biology, electronics, and automatics can be extended further. The use of semi-conductors in complex projects, especially in computers, has increased the potentialities of modern technology in an extraordinary and almost miraculous way. It has reduced the size of projects that formerly required tens and hundreds of thousands of tubes. These are so large that they can be placed only in large rooms; some are as large as big tables .

Another subject of research is the "regulation" of the mechanism of the brain, whose several million cells are located in the cranium. Though this "device" was developed during thousands of years of evolution from apparently "useless" materials (microscopic bundles of albuminous cells saturated up to 80% with water), it operates much more reliably and efficiently than the best modern radio-technical inventions. This "miracle" of nature presents a remarkable example that should be analyzed and studied not only from the standpoint of biology, but also to promote the development of electronics, radio-electronics, and automatics. Could any of these problems have been predicted twenty-five yars ago?

In conclusion, it must be repeated that the interweaving of separate disciplines, which is raising modern biology to a basically new level, does not deprive biology of its specific tasks. Primitive analogies with inanimate nature should not replace the investigation of biological processes.

Profound research on the chemistry and physics of life and examination of biological processes from the point of view of present technical problems of electronics are discovering more and more about the striking originality of living beings. This originality, formerly discussed only in its most general forms, is now being revealed in all the concreteness of known material processes.

[Photograph caption]

A device for X-ray analysis, an electronic microscope, a spectrophotometer. Twenty-five years ago biologists would never have thought that not only experienced scientists, but also graduating students and even "green" students would work with such complex and exact instruments. Nevertheless, you see a representative of the new science of biophysics in the photograph of our photo-correspondent V. Akhlomov: Yuriy Yerokhin, graduate student in the biophysics section of the biology and soil department of the Moscow State University, is preparing a spectrophotometer for an experiment on the luminescence of chlorophyll.

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